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CONSULTING ENGINEERS



CANMET/MSL DIVISION
ENERGY, MINES & RESOURCES CANADA
EVALUATION OF POZZOLANIC PROPERTIES
OF DIATOMITE RESOURCES
IN NOVA SCOTIA

PROJECT NO. 4338





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March 15, 1988

Project No. 4338

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Attention: Mr. H.S. Wilson

Dear Sirs:

Re: Evaluation of Pozzolanic Properties
of Diatomite Resources in Nova Scotia

Enclosed please find six copies of our final report on the
Pozzolanic Properties of Diatomite Resources in Nova Scotia.

If you have any questions regarding this report, please
contact me at your convenience.

Yours very truly,
JACQUES, WHITFORD & ASSOCIATES LTD.

Wilbert S. Langley
Wilbert S. Langley, M.Eng., P.Eng.

WSL/sd
Enclosure

EVALUATION OF POZZOLANIC PROPERTIES
OF DIATOMITE RESOURCES IN NOVA SCOTIA
JWA PROJECT NO. 4338

FINAL REPORT

BY

JACQUES, WHITFORD AND ASSOCIATES LIMITED

Work on the project was conducted under the auspices of the
Canada Centre for Mineral and Energy Technology, Energy,
Mines and Resources Canada.

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MICROMEDIA



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SYNOPSIS

Six sources of diatomite available locally in Nova Scotia have been evaluated in the laboratory, for possible utilization as supplementary cementing materials.

The emphasis of the study was on the chemical composition and pozzolanic properties for the source material in a raw and calcined state. The study as outlined indicates that several sources have a potential use as a supplementary cementing material.

INTRODUCTION

Diatomite consists of the skeletal remains of unicellular microscopic plants known as diatoms. They generally consist of opaline or hydrous silica, with some alumina. Other impurities such as sand, clay, and organic materials are often present. Historic uses for diatomaceous earth include filters, filter aids, insulation and pozzolan for mortars and concrete.

Diatomite high in silica may be a suitable pozzolan in the form of the raw material as extracted from the earth. If the diatomite is high in organics, such as peat, calcining at $1000^{\circ}\text{C}^{(1)}$ will remove the organics and cause some fusion of the other impurities and diatoms.

The hardness of the diatom skeleton is between 4.5 and 5 on the Moh's scale of hardness. Calcination increases the hardness to between 5 and 6. The specific gravity varies from 1.9 to 2.4. Refractive index varies from 1.40 to 1.46



for natural diatomite. The high surface area of diatomite is partly responsible for its activity as a pozzolan.

Diatomite is composed of microscopic algae, of the class Bacillariophyceae. The class contains some 16,000 species.

Environmental conditions for favorable growth include the following requirements:

- a. large shallow basins for deposition,
- b. an abundant supply of soluble silica,
- c. an abundant supply of nutrients,
- d. the absence of toxic or growth inhibiting constituents in the water, and
- e. a minimum supply of clastic sedimentary materials.

After deposition, subsequent geologic forces, such as consolidation, burial and erosion protects the deposit. Chemical alteration or regional metamorphism tends to change the characteristics of the deposit.

DIATOMITE SOURCES

There are approximately 100 known deposits of diatomite in Nova Scotia.⁽²⁾⁽³⁾

Not surprising, most of these deposits are to be found in lake bottoms or underlying peat. The deposit thicknesses vary from about 300 mm to 1,200 mm. Nova Scotia diatomite has not been exploited to date for the purposes of a supplementary cementing material, although there have been several operating companies which exploited the material for fillers, absorbents, polishing mediums, etc.



Nearly all areas of Nova Scotia contain diatomite deposits; however, the more abundant deposits occur in Colchester, Digby, and Pictou Counties. No assessment is made at this time on the quality or quantities of these sources.

SAMPLING PROCEDURE AND SAMPLE PREPARATION

Identification of the sampling sites and occurrence of the diatomite deposits was carried out with Nova Scotia Department of Mines and Energy personnel prior to initiating the sampling program. Six sites were identified for sampling from work performed by the Department of Mines and Energy.

Each site was sampled at four locations using a MacAulay Peat Sampler operated from a small flat bottomed boat. At each sample location, the material was sampled to various depths depending on the extent of the deposit, and individual samples were blended in approximately equal proportions in the wet condition. Blends from each sample location were then combined in equal proportions to produce a representative sample. Material used for the various tests was sampled from the representative samples.

SAMPLING SUMMARY

The following paragraphs describe the sites and sampling carried out on each site. The color designation is given by a Munsell number which will enable cross referencing with Department of Mines data. Sample locations are shown on the Sample Location plans, Drawing No. 4338-1 to No. 4338-6.



Brora Lake

Brora Lake is located approximately 4 km southeast of Middle Barneys River in Pictou County. The lake encompasses an area of about 2.5 hectares and is relatively shallow with water depths generally between 1 and 2 m. The diatomite varies from a soft olive grey material to a very firm light grey material. The following table summarizes the sampling carried out:

Sample Location	Depth(m)	Munsell Color	Comments
1	0-0.3	5y 8/1	Soft with some organics
	0.3-0.8	5y 4/2	Soft with some organics
2	0-0.8	5y 8/1 to 5y 4/2	Mottled, occasional green lenses.
3	0-0.7	5y 7/2	Very firm.
4	0-1.0	5y 5/3	Very loose and highly organic.

McCuish's Lake

McCuish's Lake is located approximately 25 km southeast of Sydney, Cape Breton County. The site consists of a shallow lake approximately 1.4 hectares in area, and the diatomite is concentrated around the edges of the lake in shallow water and is generally an olive grey soft deposit.



Sample Location	Depth(m)	Munsell Color	Comments
1	0-0.6	2.5y 4/2	Soft with some organics
2	0-0.8	2.5y 4/2	Soft with some organics
3	0-1.5	2.5y 7/2	Becomes whiter with depth.
4	0-1.0	7.5y 7/2	Firm with occasional green lenses.

Gards and Conky Ponds

These ponds are located approximately 3 km south of East New Annan, Colchester County, in an area where previous mining operations were carried out. The ponds have a combined area of approximately 0.5 hectares and are very shallow with water depths generally less than 1 m. Two samples were obtained from each pond and are described below.

Sample Location	Depth(m)	Munsell Color	Comments
Gards Pond			
1	0-0.4	5y 8/1	Very hard and slightly mottled.
2	0-0.4	5y 8/1	Very hard.
Conky Pond			
1	0-0.5	5y 6/2	Firm with some organics
2	0-0.4	5y 8/1	Very hard.



Gamble Lake

Gamble Lake is located approximately 6 km north of Upper Bass River, Colchester County. The lake covers about 0.2 hectares and is relatively shallow with water depths generally less than 1 m. The diatomite sampled consists of a loose olive grey material overlying a very hard white material.

Sample Location	Depth(m)	Munsell Color	Comments
1	0-0.5	5y 4/2	Loose olive grey, some organics.
	0.5-0.8	5y 8/1	Very hard with white.
2	0-0.6	5y 4/2 to 5y 8/1	Very hard with white.
3	0-0.6	5y 4/2 to 5y 8/1	Very hard with white.
4	0-0.6	5y 4/2 to 5y 8/1	Very hard with white.

McQuade Lake

McQuade Lake is located approximately 15 km northwest of Halifax. The lake encompasses an area of approximately 0.7 hectares. The diatomite is predominantly located at the northwest end of the lake and consists of an olive grey material with some organics. Diatomite was also sampled on the shore of the lake at sample location No. 4.



Sample Location	Depth(m)	Munsell Color	Comments
1	0-0.4	5y 7/4	Soft with some organics
	0.4-0.8	5y 4/3	Soft with some organics
2	0-0.4	5y 4/3	Soft with some organics
	0.4-0.8	5y 7/4	Soft with some organics
3	0-0.7	5y 4/3	
		to 5y 7/4	Overlies peat.
4	0-0.8	5y 6/2	Soft with some organics

Factory Bog

Factory Bog is located on Digby Neck near Sandy River, Digby County. The site consists of a marshy area about 3 hectares in area with water depths generally less than 1 m. The site has been mined in the past for diatomite which occurs mainly as a diatomaceous peat high in organics.

Sample Location	Depth(m)	Munsell Color	Comments
1	0.6-3.0	5y 3/2	Very soft diatomaceous peat.
2	0.6-3.0	5y 3/2	Very soft diatomaceous peat.
3	0.3-2.0	5y 3/2	Very soft diatomaceous peat.
4	1.0-2.0	5y 3/2	Very soft diatomaceous peat.



CHEMICAL AND PHYSICAL REQUIREMENTS

The chemical and physical requirements of Class N pozzolans (raw and calcined material pozzolans that comply with the applicable requirements for the class as given herein, such as some diatomaceous earths; opaline cherts and shales; tuffs and volcanic ashes or pumicites, any of which may or may not be processed by calcination; and various materials requiring calcination to induce satisfactory properties, such as some clays and shales) are shown in Table 1.⁽⁴⁾

PROPERTIES OF SAMPLES FROM SIX SOURCES

Chemical Analyses

Chemical analysis were performed on samples of the diatomite which had been previously blended from multiple samples at the source. The material was dried at 110°C prior to performing the chemical analysis.

Chemical tests were performed in accordance with ASTM Designation C311 where applicable and as noted in Table 2.

Grain Size Distributions

The grain size distributions are shown on Figures 1 through 6. The samples were dried at 550°C and the size distribution determined by a computerized laser analyzer.



Specific Gravities

Specific gravities were performed in accordance with ASTM Designation C188 and are shown in Table 3. The specific gravities were performed on samples which had been dried at 550°C so as to remove substantially all organics and also on samples calcined at 1000°C. Calcined samples generally showed a higher specific gravity than the non-calcined samples.

Water Requirements

Table 4 summarizes the water requirements for each diatomite source tested for the pozzolanic activity index. Samples were prepared for the diatomite dried at 550°C and calcined at 1000°C.

The water requirements generally exceeded the allowable limits specified in ASTM C618.

Pozzolanic Activity Index with Portland Cement

The results of the pozzolanic activity index tests with Portland cement are summarized in Table 5. The tests were conducted on the raw diatomite (dried at 550°C) and on samples which had been calcined at 1000°C.

The samples calcined at 1000°C gave equal or lower pozzolanic activity indexes than the raw diatomite.

Pozzolanic Activity Index with Lime

Table 6 summarizes the data on pozzolanic activity index with lime. The tests were conducted in accordance with ASTM



Designation C311. McCuish's Lake and McQuade Lake dried at 550°C met the strength requirements of 5500 kPa. Brora Lake and Gards and Conky Ponds met the requirements when calcined at 1000°C.

Increase of Drying Shrinkage of Mortar Bars

The increase in drying shrinkage of mortar bars conducted in accordance with ASTM Designation C311 is shown in Table 7 for each of the sources tested in both a raw and calcined state.

The calcined diatomite showed less shrinkage than the raw diatomite. Each of the raw samples tested failed the ASTM shrinkage criteria of 0.03 percent maximum increase.

PROPERTIES OF PORTLAND CEMENT USED IN TESTS

Chemical Analysis of Cement

The chemical analysis of the Portland cement Type 10 used in the diatomite testing is shown in Table 8.

Physical Properties of Cement

The physical properties of the Portland cement Type 10 used in the diatomite testing is shown in Table 9.

CONCLUSIONS

Samples of diatomite from six sources have been characterized for use as a supplementary cementing material. Five of the six showed pozzolanic activity indexes in excess of the 75



required by ASTM Designation C311. Two of the locations met or exceeded the 5500 kPa strength requirement with lime. All of the samples exceeded the specified water requirement of 115 percent.

Samples of the diatomite were tested after drying at 550°C and after calcination at 1000°C and regrinding. Calcination did not improve the pozzolanic activity index but did improve the shrinkage. Phase changes of some of the silica may have influenced some test parameters.

The test results are generally considered to have yielded positive results and the test results could probably be improved by processing the diatomite at different temperatures prior to testing.

The viability of using diatomite in concrete would necessarily depend on the cost of reclaiming the material at the source and subsequent drying and preparation. The performance of the diatomite in concrete would have to be established. Significant properties to be evaluated would include alkali-aggregate reaction, sulphate resistance, and water demand.

REFERENCES

- (1) Mineral Processing Handbook, Weiss, Norman L., Editor in Chief, Society of Mining Engineers.
- (2) Diatomaceous Earth and Fuller's Earth in Nova Scotia, Nova Scotia Department of Public Works and Mines.

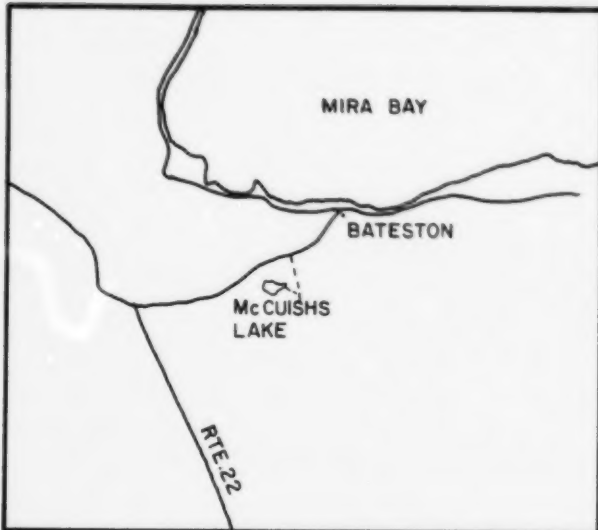


- (3) Open File Report 606, Industrial Mineral Occurrences Map and Data Compilation - Canada - Nova Scotia Mineral Development Agreement.
- (4) Annual Book of Standards, ASTM 1987 Section 4, Vol. 04.02 Concrete and Aggregate - Designation C618-85.



DRAWINGS





LOCATION PLAN
N.T.S.



SAMPLE LOCATIONS



Mc CUISHS LAKE

DIATOMITE SAMPLE LOCATIONS

Scale:

1:5000

Dwg. No.:

4338-1

Date:

1/02/88

Dwn. by:

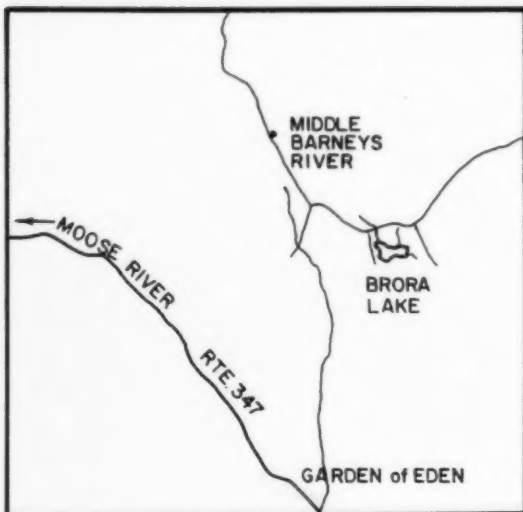
R.L.F.

Appd:

DMN

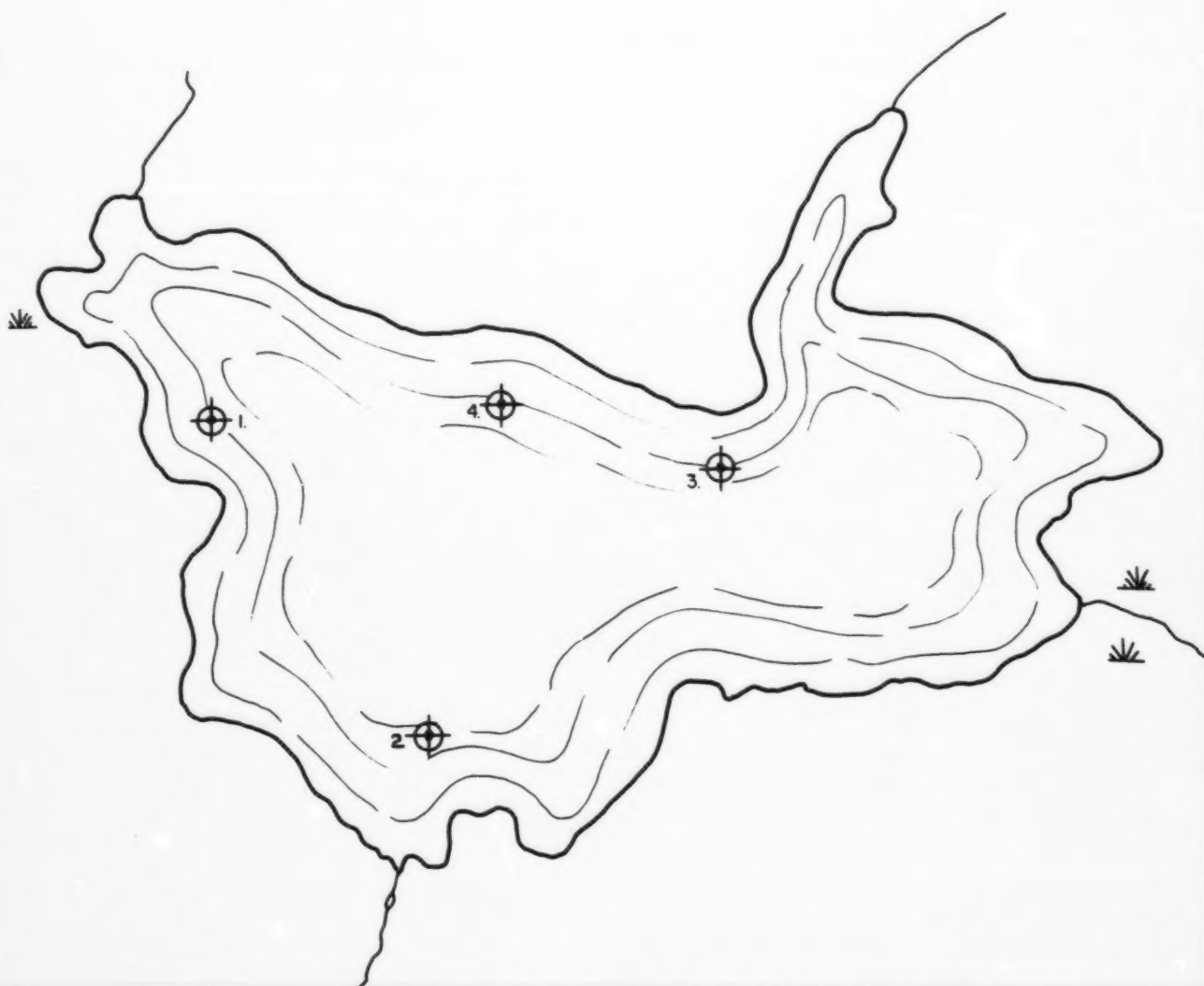


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SAMPLE LOCATIONS

LOCATION PLAN
N.T.S.



BRORA LAKE
DIATOMITE SAMPLE LOCATIONS

Scale:

1:5000

Dwg. No.:

4338-2

Date:

29/1/88

Dwn. by:

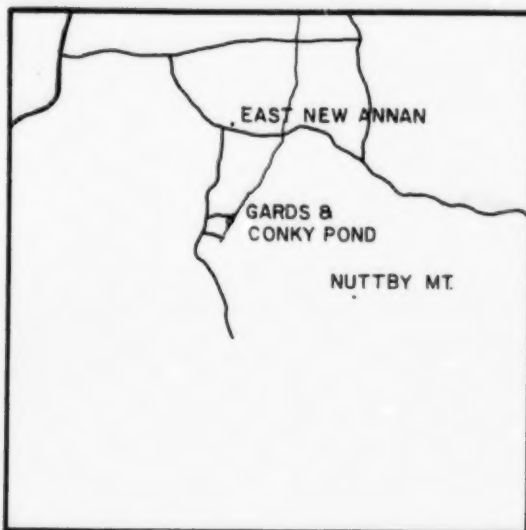
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Appd:

2/1/1



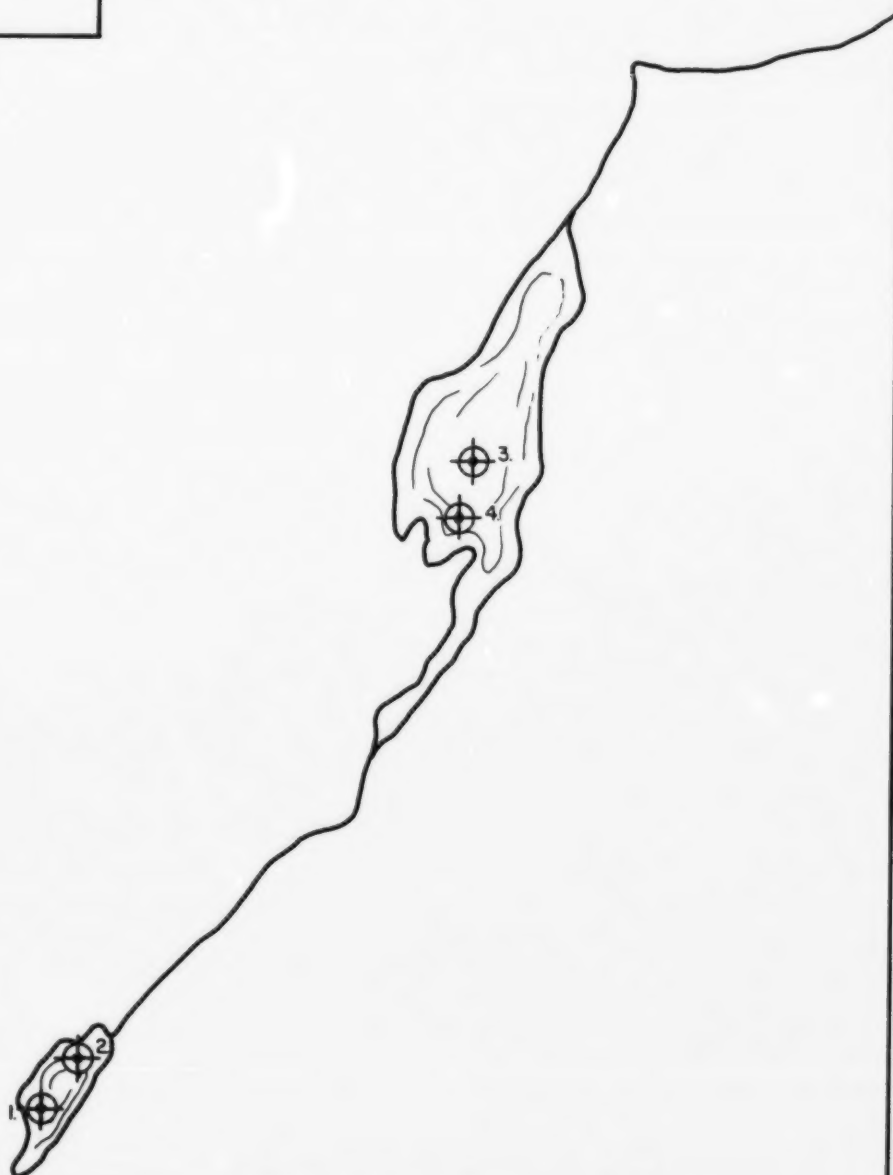
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LOCATION PLAN
N.T.S.



SAMPLE LOCATIONS



GARDS & CONKY POND
DIATOMITE SAMPLE LOCATIONS

Scale:

1:5000

Dwg. No.:

4338-3

Date:

1/02/88

Dwn. by:

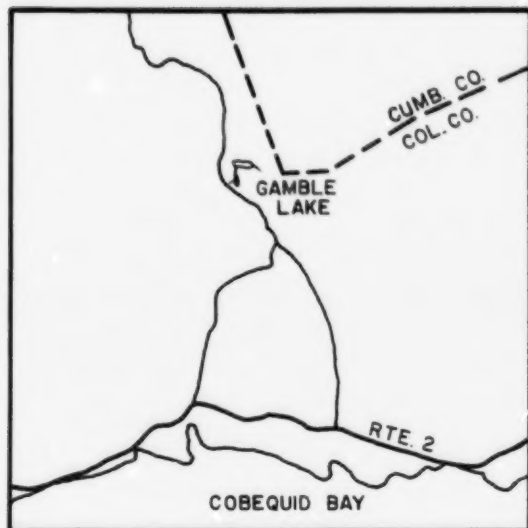
R.L.F.

Appd:

gmin



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LOCATION PLAN
N.T.S.



SAMPLE LOCATIONS



GAMBLE LAKE
DIATOMITE SAMPLE LOCATIONS

Scale:
1:5000

Dwg. No.:
4338-4

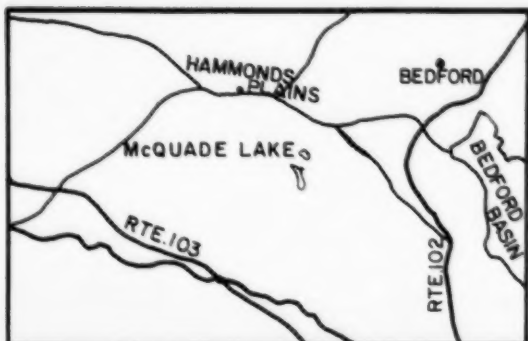
Date:
1/02/88

Dwn. by:
R.L.F.

Appd:
JMM



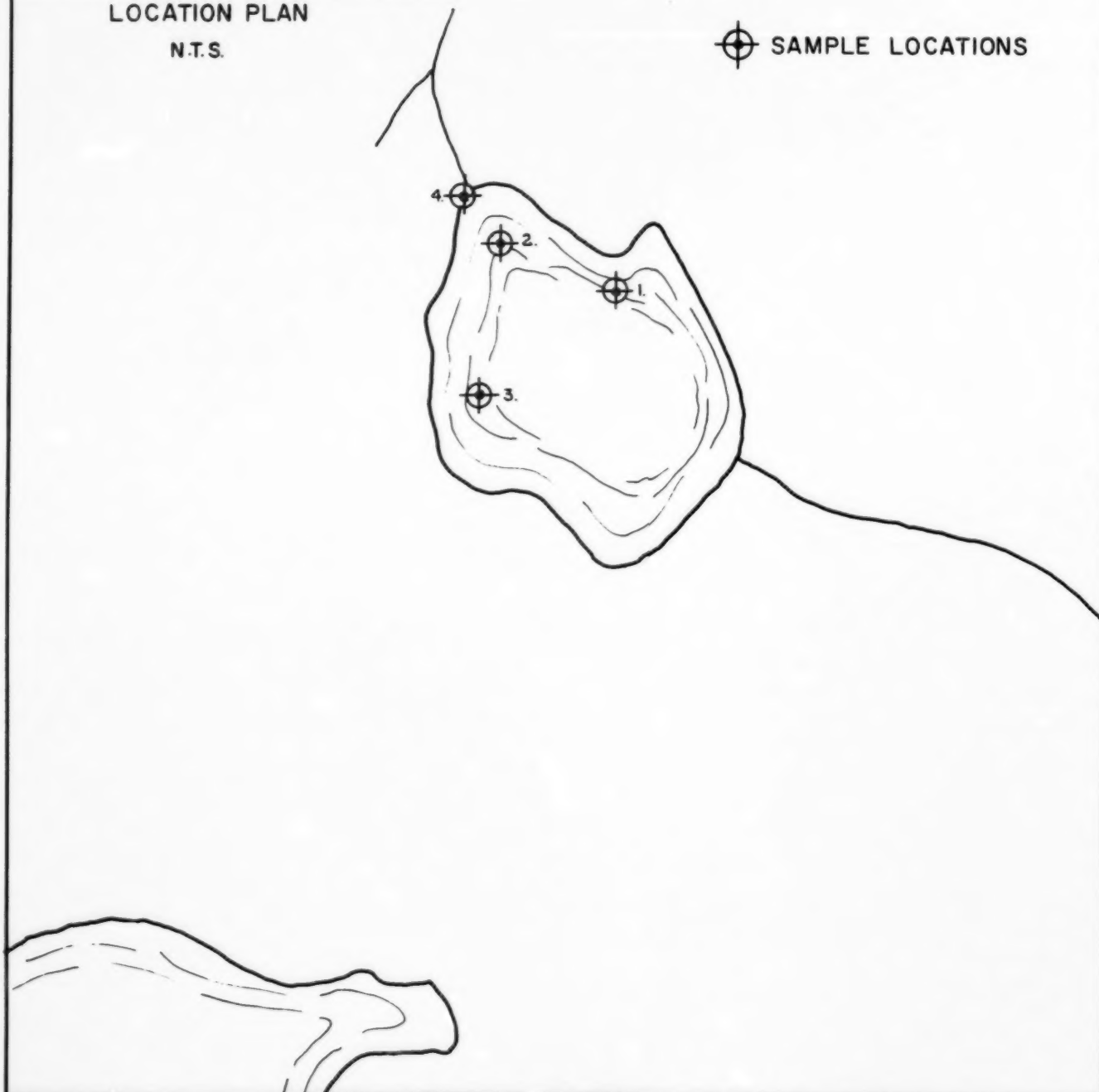
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LOCATION PLAN
N.T.S.



⊕ SAMPLE LOCATIONS

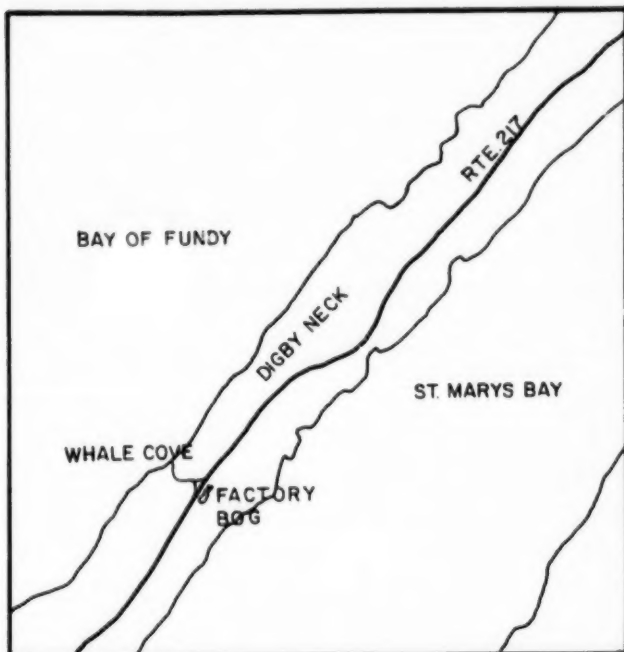


McQUADE LAKE
DIATOMITE SAMPLE LOCATIONS

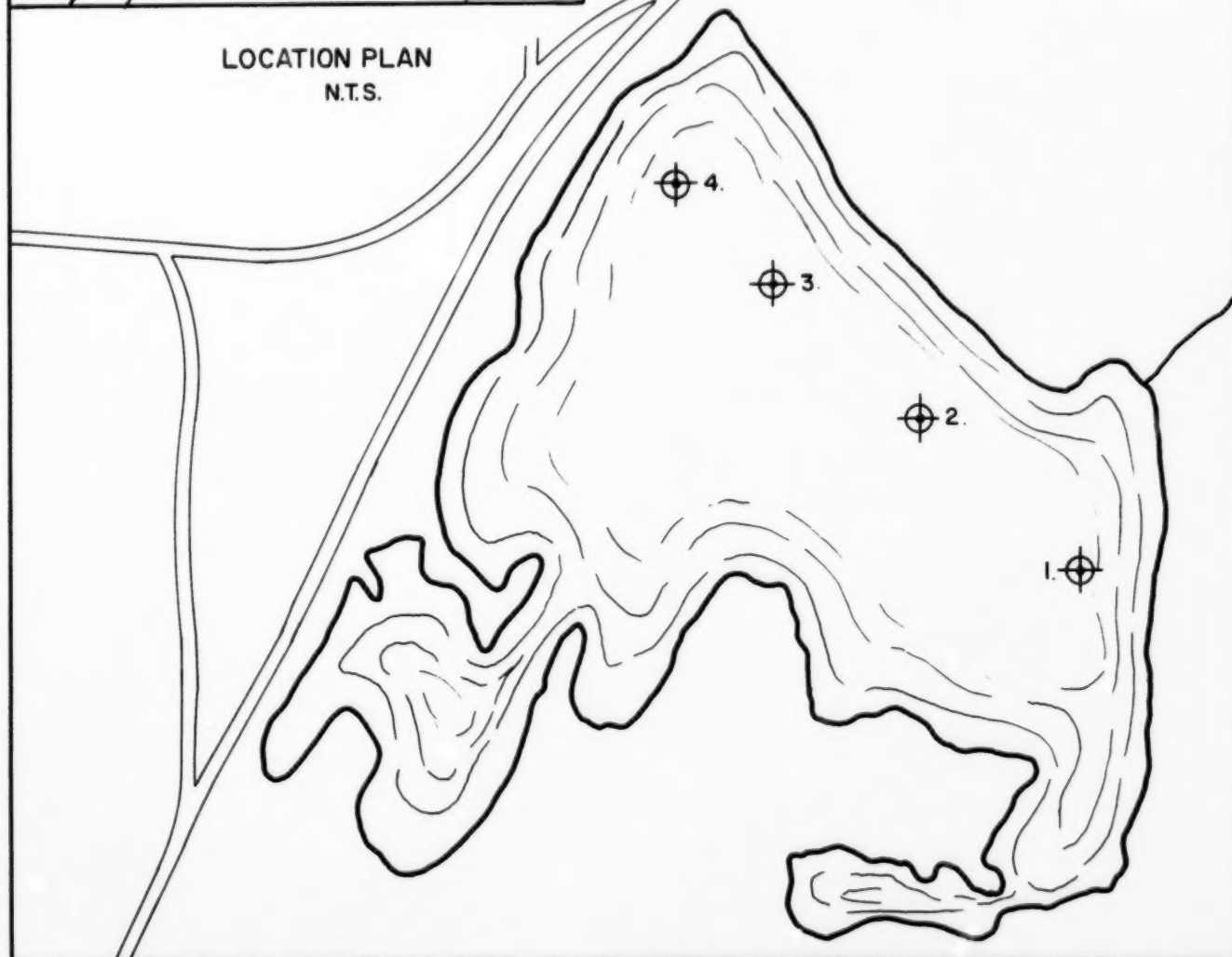
Scale:	Dwg. No.:	
1:5000	4338-5	
Date:	Dwn. by:	Appd:
10/2/88	R.L.F.	Jmr



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LOCATION PLAN
N.T.S.



SAMPLE LOCATIONS

FACTORY BOG
DIATOMITE SAMPLE LOCATIONS

Scale:
1:5000

Dwg. No.:
4338-6

Date:
29/1/88

Dwn. by:
R.L.F.

Appd:
JMN

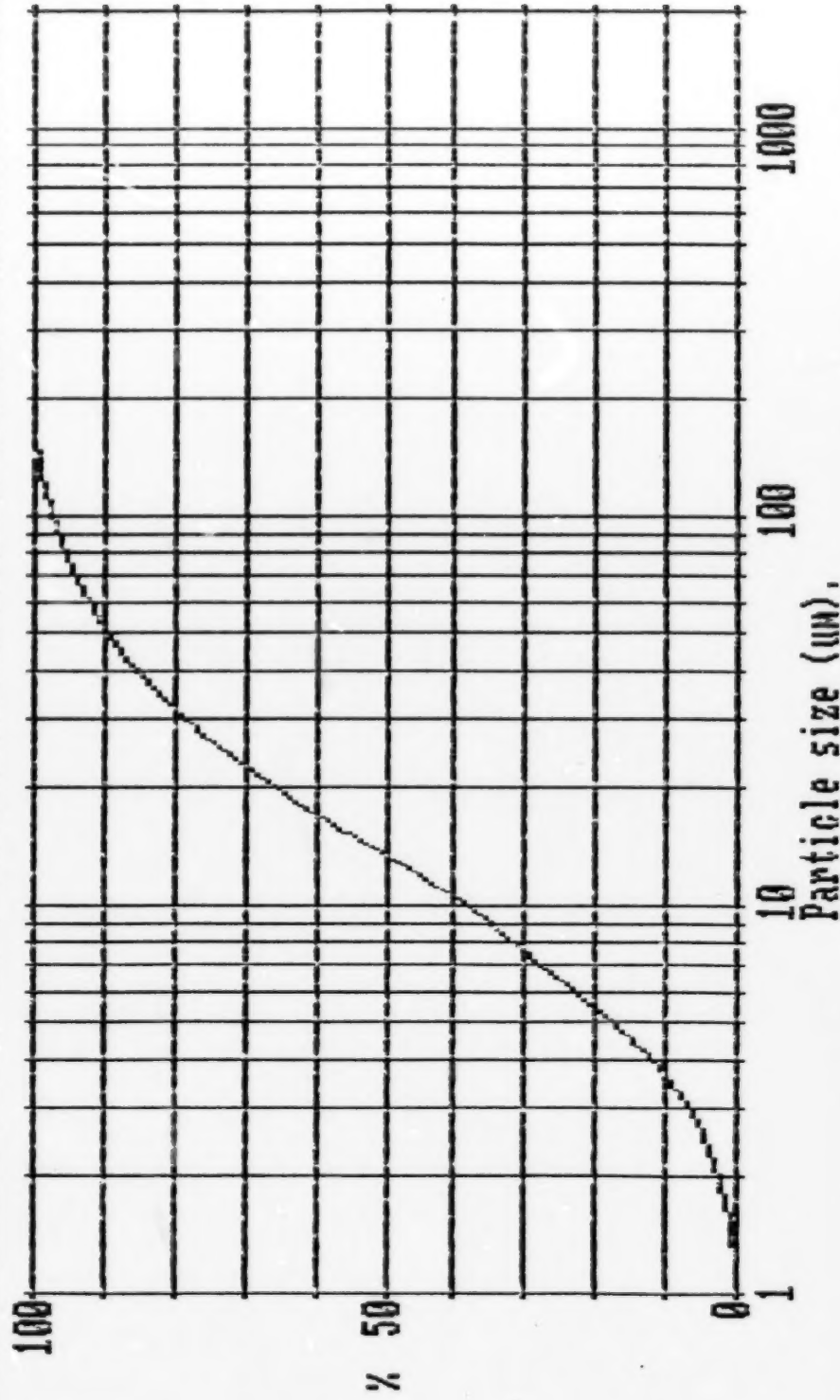


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FIGURES



Malvern Instruments EASY Particle Sizer M3.1 Date 22-12-87 Time 13-59

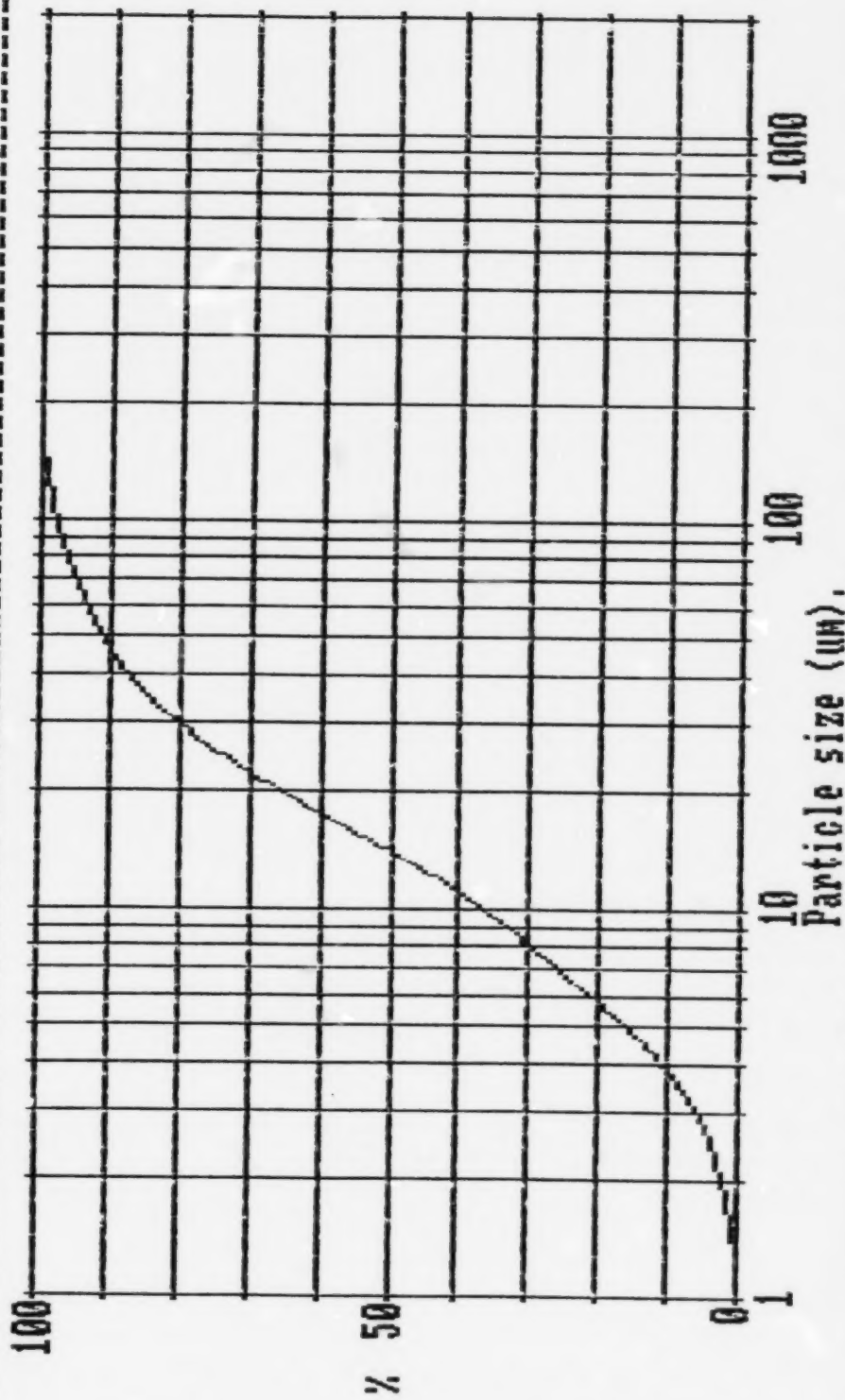


Sample details: - Jacques Whitford & Associates
Diatomite Samples - Job #4338
Sample Bora Lake

J.P.

FIGURE 1

Malvern Instruments EASY Particle Sizer M3.1 Date 22-12-87 Time 13-40

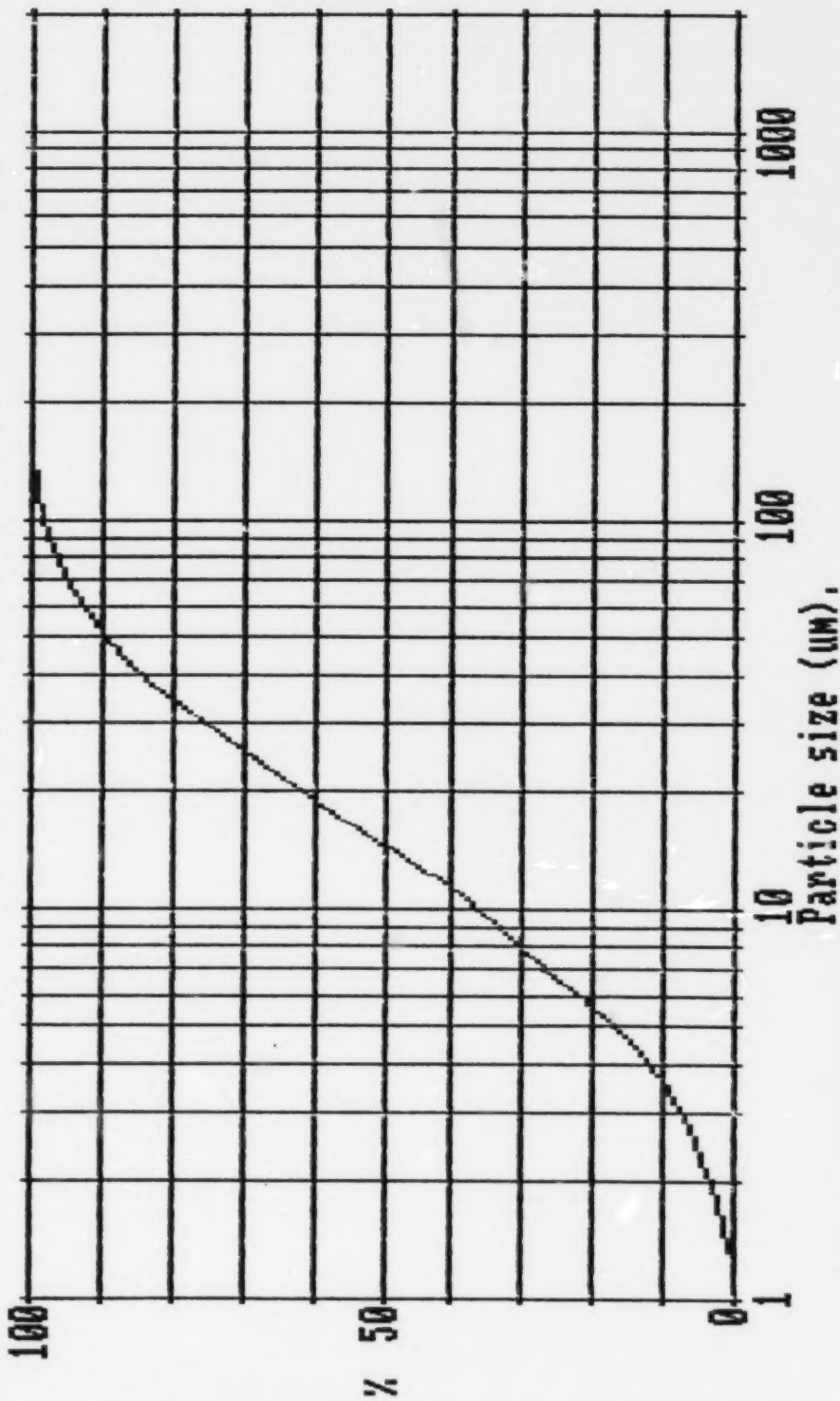


Sample details:- Jacques Whitford & Associates
Diatomite Samples - Job #4338
Sample McGuish

J.P.

FIGURE 2

Malvern Instruments EASY Particle Sizer M3.1 Date 22-12-87 Time 13-13

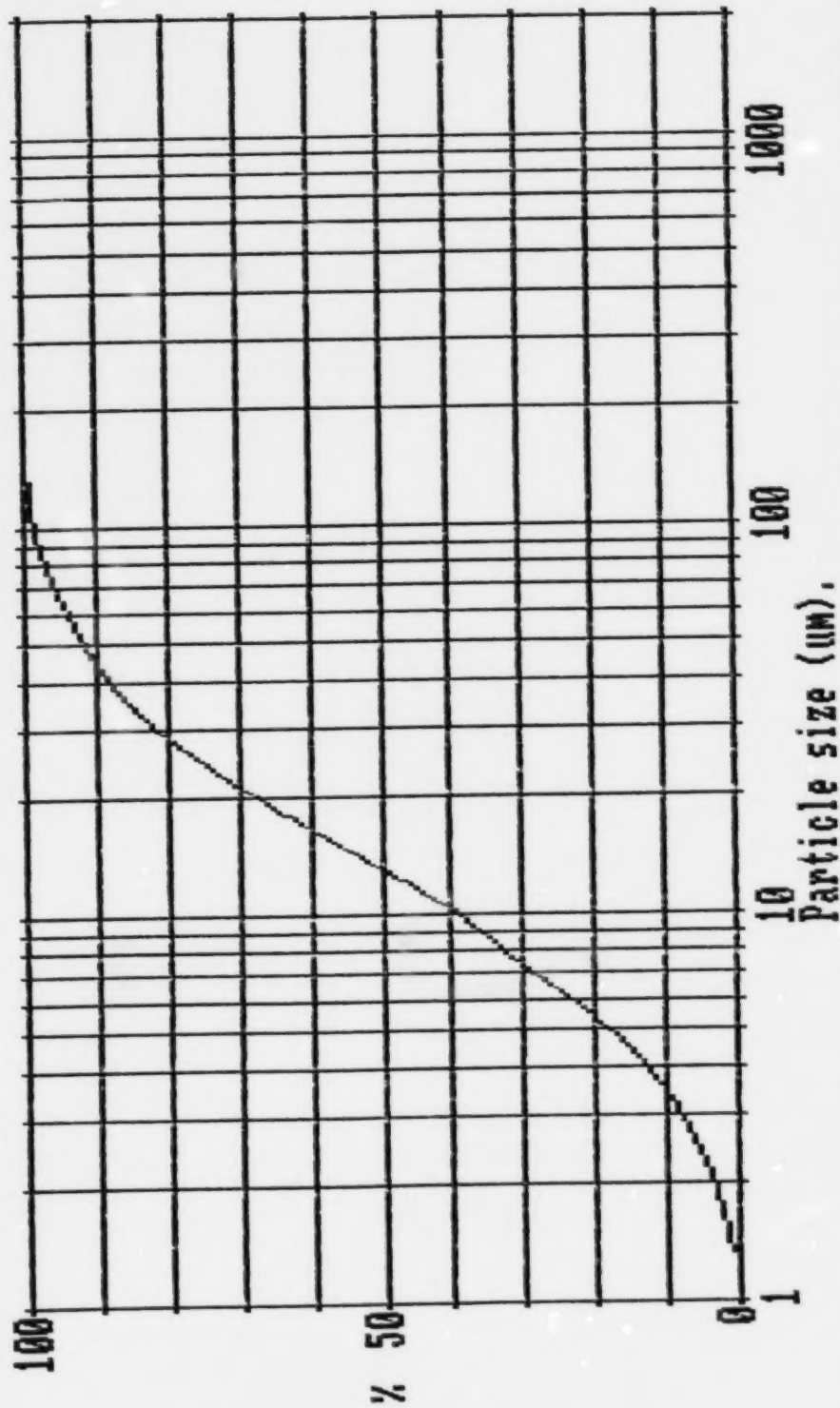


Sample details:- Jacques Whitford & Associates
Diatomite Samples - Job #4338
Sample Conky & Gonds

J.P.

FIGURE 3

Malvern Instruments EASY Particle Sizer M3.1 Date 22-12-87 Time 13-27

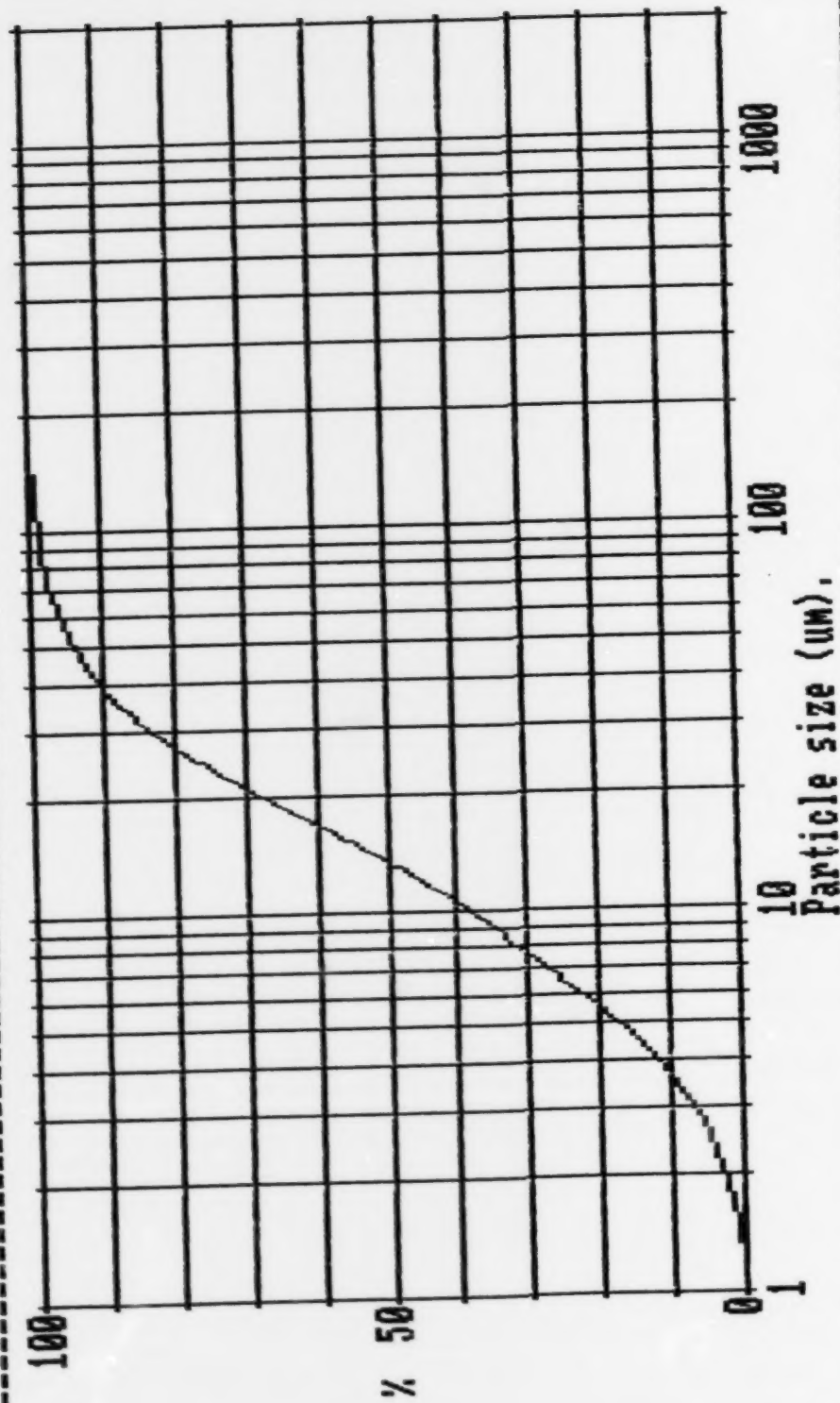


Sample details:-Jacques Whitford & Associates
Diatomite Samples - Job #4338
Sample Gamble

J.P.

FIGURE 4

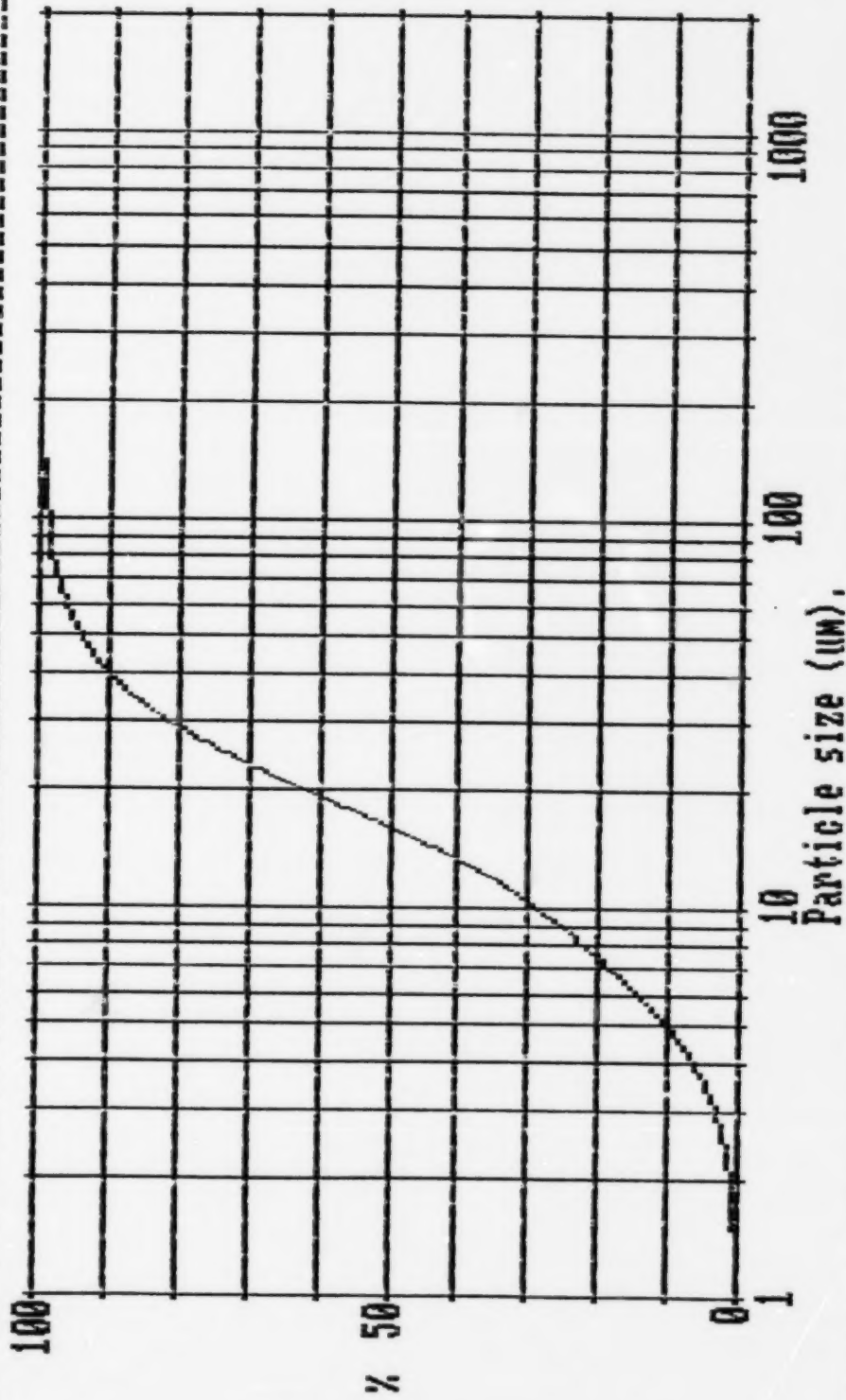
Malvern Instruments EASY Particle Sizer M3.1 Date 22-12-87 Time 12-59



Sample details:- Jacques Whitford & Associates
Diatomite Samples - Job # 4338
Sample McQuade

FIGURE 5

Malvern Instruments EASY Particle Sizer M3.1 Date 22-12-87 Time 13-50



Sample details:- Jacques Whitford & Associates
Diatomite Samples - Job #4338
Sample Factory Bag

J.P.

FIGURE 6

TABLES



TABLE 1

MINERAL ADMIXTURE CLASS N
ASTM DESIGNATION C618

CHEMICAL REQUIREMENTS

Silicon dioxide, Aluminum oxide, Iron oxide, min. %	70.0
Sulfur trioxide, max. %	4.0
Moisture Content, max. %	3.0
Loss on Ignition, max. %	10.0

PHYSICAL REQUIREMENTS

Fineness - Max. % retained on 45 μ m	34
Pozzolanic Activity Index	
With Portland Cement - min % of control @ 28 days	75
With Lime - compressive strength @ 7 days (min. kPa)	5500
Water requirement, max. % of control	115



TABLE 2

CHEMICAL ANALYSIS

	Conky & Gards	McQuade	Factory Bog	Gamble	McCuish's	Brora Lake
*SiO ₂	83.95	70.66	52.30	83.00	79.55	83.81
*Al ₂ O ₃	1.59	8.22	2.17	1.98	3.30	1.79
*Fe ₂ O ₃	0.62	2.88	1.48	1.21	1.27	1.03
*CaO	0.16	0.59	1.00	0.57	0.62	0.50
MgO	0.27	0.43	0.36	0.25	0.34	0.26
Na ₂ O	0.26	0.59	0.21	0.18	0.30	0.22
K ₂ O	0.18	0.94	0.01	0.15	0.09	0.13
*L.O.I. (750°C)	10.99	14.59	38.01	11.65	11.83	10.65
P ₂ O ₅	0.03	0.23	0.11	0.04	0.15	0.08
*SO ₃	0.21	0.25	0.48	0.41	0.64	0.26

* ASTM DESIGNATION C311



TABLE 3

SPECIFIC GRAVITY
ASTM DESIGNATION C188

SITE	SG @ 550°C	SG @ 1000°C
Brora Lake	1.93	2.24
McCuish's Lake	2.00	2.01
Conky & Gards	1.87	2.07
Gamble Lake	1.94	2.02
McQuade Lake	2.08	2.39
Factory Bog	2.01	2.11



TABLE 4

WATER REQUIREMENT
ASTM DESIGNATION C311

SITE	WATER REQUIREMENT (ml)			
	550°C	% of Control	1000°C	% of Control
Control	125	----	----	----
Brora Lake	165	132	170	136
McCuish's Lake	170	136	170	136
Conky & Gards pond	165	132	170	136
Gamble Lake	160	128	170	136
McQuade Lake	160	128	170	136
Factory Bog	180	144	180	144



TABLE 5

POZZOLANIC ACTIVITY INDEX
WITH PORTLAND CEMENT
ASTM DESIGNATION C311

SITE	Pozzolanic		Pozzolanic	
	550°C	Activity Index	1000°C	Activity Index
Brora Lake	25 MPa	78	22	69
McCuish's Lake	29 MPa	91	23	72
Conky & Gards pond	24 MPa	75	24	75
Gamble Lake	26 MPa	81	23	72
McQuade Lake	27 MPa	84	20	63
Factory Bog	22 MPa	69	22	69

* Control 32 MPa



TABLE 6

POZZOLANIC ACTIVITY INDEX
WITH LIME
ASTM DESIGNATION C311

Site	Compressive Strength (kPa)	
	550°C	1000°C
Brora Lake	3700	5600
McCuish's Lake	5700	4300
Conky & Gards	3400	6000
Gamble Lake	5000	5100
McQuade Lake	8300	4000
Factory Bog	--	4700



TABLE 7

INCREASE OF DRYING SHRINKAGE OF MORTAR BARS
ASTM DESIGNATION C311

Site	Shrinkage % 550°C	Increase % Beyond Control	Shrinkage % 1000°C	Increase % Beyond Control
Brora Lake	0.16	0.08	0.10	0.02
McCuish's Lake	0.16	0.08	0.11	0.03
Conky & Gards Pond	0.17	0.09	0.12	0.04
Gamble Lake	0.17	0.09	0.11	0.03
McQuade Lake	0.13	0.05	0.09	0.01
Factory Bog	0.17	0.09	0.11	0.04

* Control 0.08 percent shrinkage.



TABLE 8

CHEMICAL ANALYSIS OF CEMENT

	TYPE 10

SiO ₂	20.23
Al ₂ O ₃	5.33
Fe ₂ O ₃	2.65
CaO	61.7
MgO	1.66
Na ₂ O	0.12
Na ₂ O (equivalent)	0.91
K ₂ O	1.19
SO ₃	4.30
C ₂ S	18.1
C ₃ S	49.3
C ₃ A	9.6
C ₄ AF	8.0
Loss on Ignition	2.61



TABLE 9

PHYSICAL PROPERTIES OF CEMENT

Type 10

Normal Consistency	24.5
Initial Set (Vicat)	120 min
Final Set (Vicat)	227 min
% Finer Than 75 μm	94.4
% Finer Than 45 μm	84.1
Blaine Fineness	380 m^2/kg

Compressive Strength,
MPa (50 mm Cubes)

3d	26.8
7d	32.9
28d	36.7

